THE OSTEOLOGY OF CAULARCHUS MÆANDRICUS (GIRARD).

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The family Gobieosocidæ to which *Caularchus* belongs was at one time associated with the family Liparidæ on account of a ventral sucking disk possessed by both of them. Dr. Gunther[1] in 1861 worked out the anatomy of the disks, and showed that they were very different in structure. There being no other similarities between these two families the Gobieosocidæ has since that time been variously placed in the suborder Acanthopteri by different authors, as near the Blenniidæ, the Gobiidæ or the Batrachoididæ. Apparently the most rational disposition of the family has been made by Dr. Gill, who created for it the order Xenopterygii, which he placed with other orders of doubtful relationship with which it had nothing in common.

In undertaking the following work my interest was (1) to work over and describe the many osteological peculiarities of *Caularchus*, and (2) to attempt to find some indication of its relationship and systematic position. In the latter I have had small success, and I present this paper with reference to what anatomical value it may have.

The form I have chosen is *Caularchus mæandricus*, a species taken in abundance on the California coast. I have also examined *Gobiesox sanguincus* from the coast of Peru, and have added notes on its characters where they differ from those of *Caularchus*.

Cranium.

The cranium is much compressed and as wide as it is long. The vomerine region is broadly notched in front. On the superior surface and extending back to between the posterior margins of the orbits is a broad depression for the reception of the flat premaxillary processes. There is no supraoccipital crest and only very low temporal crests, which are connected across the

[1] Catalogue of Fishes of the British Museum, III., p. 495.

parietal region by a low transverse ridge. Long lateral processes from the prefrontal and sphenotic bound the orbital region. Broad wings from the sides of the parasphenoid form a wide floor anterior to, and in continuation with, the floor of the brain-case. The basisphenoid and opisthotic are absent. There is no myodome. In *Gobiesox* the anterior portion of the cranium is scarcely depressed for the reception of the premaxillary processes.

The basioccipital is a flat bone not turned up at its lateral edges, and the greater part of it is covered by the wide parasphenoid. Its condyle is depressed, ellipitical in shape, and slightly inclined upward in opposition to the exoccipital condyles which are slightly inclined downward.

The exoccipitals are widely separated by the interposition of the basioccipital between them. They assist the latter bone in connecting the cranium with the vertebral column, presenting a round condyle at each side of the basioccipital condyle, so that the three parts of the basioccipital condyle are on a horizontal line.[1]

The surface of the supraoccipital is divided into two parts by the meeting of the parietals over its middle. The visible anterior portion of the supraoccipital thus separated from the posterior portion is nearly round in outline. In a few of the specimens examined the parietals just touch, in none of them do they meet broadly. In *Gobiesox* the parietals are well separated by the supraoccipital, extending over the edge of the latter only slightly.[2]

[1] The condyles of the exoccipitals are wholly lateral to that of the basioccipital only in those fishes with a much depressed form, as *Callionymus*, *Remora* or *Caularchus*, though it does not at all follow that all fishes with depressed forms have lateral occipital condyles. It appears to be the rule that fishes with a depressed form never have the condyles of the exoccipitals wholly superior and in contact with each other, while those with a compressed form never have them wholly lateral.

[2] The condition of the meeting of the parietals should be more fully reported upon in other forms. Their union or separation by the supraoccipital has been used in the past in distinguishing large groups, and though the character has doubtless much less value than has been ascribed to it, its real value can not be known until it is more fully investigated. The difference between the condition of the parietals in *Caularchus* and *Gobiesox* is but a difference in degree where in one form they develop over the supraoccipital a little further than in the other and meet. This condition obviously has not the importance it has in some of the cyprinoid fishes where the parietals meet broadly entirely in front of the supraoccipital, and are the roof bones of the cranium in this region. The brief statement "parietals meeting" or "parietals separated by the supraoccipital" is far from being adequate. The condition of the parietals in *Caularchus* is not a very unusual one.

There is a notch on the posterior lateral surface of the epiotic formed between a short process above and the projecting lower edge of the epiotic below, into which the head of the posttemporal is received.

A long process projecting from the lateral edge of the pterotic passes along the posterior edge of the hyomandibular, and reaching almost to the opercle rigidly holds the suspensorium obliquely outward. A similar process formed by the sphenotic and the posterior end of the frontal projects over the anterior edge of the hyomandibular head, and forms the posterior orbital margin.

The frontals are broad and their anterior part as far back as the posterior margin of the eyes bears a large square depressed area in which the long flat premaxillary processes play.

The parasphenoid reaches its greatest width at its extreme anterior end where two wings reach far out on the prefrontals. It grows narrower below the orbital region, but again broadens in front of the proötics, and thence tapers quickly to a point at the posterior end.

The opposing proötics nearly meet at the median line above the parasphenoid, and in front of the basioccipital. The main parts of the fifth and seventh nerves occupy a notch in the anterior part of the proötic, but a small branch of the former runs through a small foramen just behind the notch.

The prefrontal is a wide bone projecting laterally in front of the orbital cavity, and supported behind by the broad parasphenoid. It is pierced near its center by the olfactory nerve.

The ethmoid is disk-shaped and apparently wholly membranous in origin. It is situated between the anterior ends of the frontals and does not extend in front of them.

The vomer is very broad, having a broad shallow notch in its anterior end, and with its lateral angles projecting. In a notch formed between each lateral angle of the vomer and the end of the palatine the maxillary fits just above its middle.

The Lateral Bones of the Head.

The hyomandibular, where it articulates with the cranium, terminates in two knobs, which fit into concavities in the sphenotic and pterotic. Below it has three articular processes; one for the

opercle, one for the preopercle (by far the largest), and one divided between the symplectic and interhyal.

The symplectic is a slender bone bridging a large open space in front of the preopercle, and is the only bone between the hyomandibular and the quadrate in this region. It is received in a deep wedge-shaped notch, cut entirely to its tip, in the quadrate. The mesopterygoid and metapterygoid being absent the symplectic forms part of the anterior border of the cheek bones. In *Gobiesox* the symplectic runs behind the quadrate as usual, cutting from the latter only a small notch.

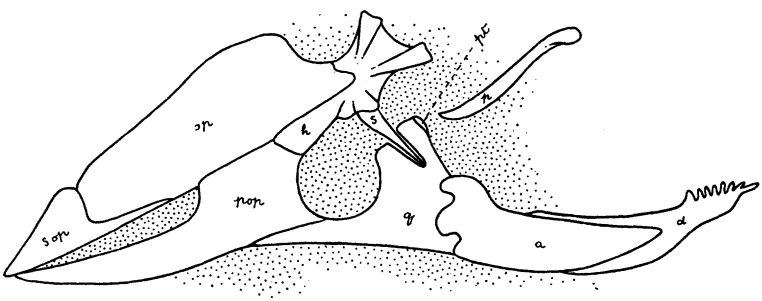

FIG. 1. Lateral bones of skull. *a*, articular; *d*, dentary; *h*, hyomandibular; *op*, opercle; *p*, palatine; *pt*, pterygoid; *pop*, preopercle; *q*, quadrate; *s*, symplectic; *sop*, subopercle.

The quadrate extends back covering the front of the preopercle. Above it is a very large open space, nearly circular in outline, bounded behind by the preopercle, and above and before by the hyomandibular and symplectic.

A small bone closely attached to the upper anterior edge of the quadrate is all that remains of the pterygoid. To it the palatine is attached by a ligament. It is very inconspicuous, and so closely united to the quadrate that it appears as a part of that element, but is easily separated in a macerated specimen.

The palatine is free from the other cheek bones, and is only connected to the reduced pterygoid by a ligament. Anteriorly it hooks over the maxillary.

The mesopterygoid and metapterygoid are entirely absent.

The articular is hinged to the quadrate by a very wide horizontal joint, making the jaw very rigid laterally. At the upper posterior angle is a strong process. There is no open space between the articular and the upper limb of the dentary.

The dentary is a strong bone and so closely attached to the articular that there is no play between them as is usual in other forms.

The angular is a very small nodule of bone on the inner surface of the articular, entirely hidden when the skull is viewed laterally. The interopercle is attached to the angular by a ligament.

The opercle, preopercle and subopercle together form an isosceles triangle with its greatest length extending backwards. The subopercle forms the posterior point of the triangle, and is interposed between the points of the opercle and preopercle. The preopercle is developed backward from its articulation with the hyomandibular to a long point, forming nearly the entire lower border of the opercular system. It forces itself between and entirely separates the subopercle and interopercle, bringing the opercle entirely above it. Its anterior end extends forward in a long point behind the quadrate nearly to the mandibular condyle. The interopercle is a small triangular bone, lying free behind the quadrate and hidden from sight by that bone when the skull is viewed laterally. It is unconnected except by a ligament to the angular. There is a low ridge running along the lower edge of the opercle, and a very high sharp one running along the lower edge of the preopercle and the quadrate nearly to the condyle of the mandible.

A broad membranous preorbital plate is all that remains of the suborbital chain of membrane bones. It bears a sensory tube which opens anteriorly to the exterior through a small pore a couple of millimeters in front of the anterior nostril. The tube crosses the plate obliquely downward and backward, forking widely in front of the eye, and opening to the exterior at the lower edge of the plate through two widely separated pores. These pores appear in the skin at the upper border of the mouth 6 or 7 mm. apart.[1] A third pore 4 mm. anterior to these, and near the front of the mouth, forms the exit of the sensory tube traversing the nasal plate.[2] At the place the preorbital tube forks the plate is slightly ossified.

[1] The specimen described is 1 cm. in length.

[2] It appears probable that the suborbital sensory tube is never present in the Teleosts unossified. There may be a series of pores or nerve hillocks, as in *Porichthys*, but they do not open into a continuous tube. I have examined a large number of forms known to have no suborbital bones, but find no tube present in any of them.

The maxillary elements are very strong. The premaxillaries send back long wide processes over the top of the head to between the eyes. Each maxillary bears a notch on its upper surface for the reception of the edge of the premaxillary process. The notch is some distance from the head of the maxillary and allows it to meet its opposite fellow below the premaxillary processes, but viewed from above the maxillaries appear to be widely separated. There is a depression in the upper surface of each maxillary into which the palatine fits.

The nasals are wide bones meeting on the median line, covering the anterior part of the premaxillary processes, and interposed between the maxillaries above.

The Branchial and Hyoid Bones.

The basibranchials are entirely absent, and the hypobranchials are but slightly separated at the median line. The latter are all of the same length, very long and much constricted at the middle. They appear to be entirely cartilaginous in a fresh skeleton, but as they dry a fine hard calcareous matter becomes evident. The hypobranchial of the fourth arch is missing, as in all other teleosts (so far as known). The ceratobranchial of the fourth arch is as long as the combined length of the ceratobranchial and the hypobranchial of the third arch,[1] and opposite the union of these two elements it is angulated, so that its lower part has the appearance of being the fourth hypobranchial. The superior pharyngeals of each side are anchylosed into a single tooth-bearing bone. The inferior pharyngeals are in contact only at their anterior ends.

A very small nodule of bone between the hypohyals on the lower surface represents the urohyal, and another on the upper surface the glossohyal. Only one of the hypohyal elements is present on each side. The suture between the hypohyal and the ceratohyal runs vertically upward from the lower side of the arch half way across the arch, then turns squarely and runs horizontally backward for nearly half the length of the ceratohyal, where

[1] I am not aware of any similar arrangement in any other Teleost. The hypobrachials usually decrease in length so rapidly posteriorly that their absence on the fourth arch does not require a lengthening of the fourth ceratobranchial; all of the ceratobranchials being of about the same length.

it again turns upward and reaches the upper side of the arch. The other hyoid elements are normal. Six branchiostegal rays are present; two are attached to the outer surface of the epihyal, two to the outer surface of the ceratohyal, and two to the inner surface of the ceratohyal. In *Gobiesox* the urohyal and glossohyal are better developed, the former being scarcely reduced.

The Shoulder and Pelvic Girdles.

The posttemporal is a long simple ray of bone inclined obliquely outward and forward from its attachment with the cranium, so that its outer end is farther forward than its inner. It thus forms a sharp angle with the supraclavicle, which is inclined forward as usual. In place of the usual lower limb a long liga-

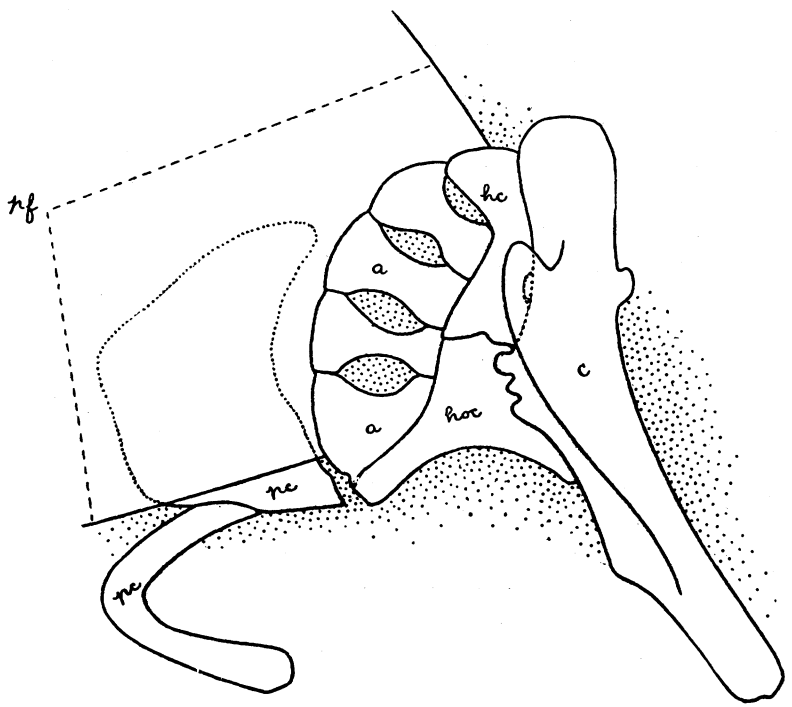

Fig. 2. Shoulder girdle. *a*, actinosts; *c*, clavicle; *hc*, hypercoracoid; *hoc*, hypocoracoid; *pf*, pectoral fin; *pc*, post clavicle.

ment connects it with the inner edge of the exoccipital near the basioccipital. Its proximal end is not very firmly attached to the cranium. A short epiotic process projects over its head, and

two stout ligaments are attached to it, one above and one below, holding it firmly against the epiotic, but leaving it movable laterally.

The supraclavicle is a long simple bone. At its lower end is a concavity which fits over a knob on the clavicle.

The clavicle is slightly bent at an angle near its middle. From its anterior edge a large lateral wing projects outward and backward. A short distance above its middle on its anterior edge is a tubercle of bone over which the cup-shaped end of the supraclavicle is attached.

The hypercoracoid is constricted at its middle opposite the base of the upper actinost so that it appears as a fifth actinost.[1] This illusion is enhanced by the pectoral fin being joined to it by two or three rays. It lies along the entire length of the upper actinost, but is separated from it, except at each end, by an open space similar to that between the actinosts. As the clavicle overlaps the hypercoracoid to the edge of the hypercoracoid foramen the foramen appears to be between these two bones. It is, however, through the middle of the hypercoracoid.

The hypocoracoid is joined as usual to the clavicle and hypercoracoid but its lower end instead of returning to the lower end of the clavicle, as usual in most fishes, projects backward along the lower edge of the lowest actinost. This condition is evidently brought about by the position of the pelvic girdle which is closely attached along the inner lower edge of the clavicle.

The actinosts are hour-glass-shaped, four in number, and separated from each other by open spaces. The coracoid elements each support two actinosts.

The postclavicle has lost its attachment with the clavicle and lies free opposite the base of the pectoral fin just behind the pelvic girdle. It is divided into two parts. The inferior portion is curved around the outer and posterior portions of the ventral disk, and the posterior fringe of the disk is attached to its edge. The superior portion is very broad and from its posterior edge is developed the peculiar fin-like flap seen externally on the fish just behind the pectoral fin. In *Gobiesox* a flat process is devel-

[1] In the accompanying drawing this loses its deceptive appearance on account of the exaggeration of the distinctness of the sutures.

oped forward from the upper element of the postclavicle to the upper end of the clavicle.

The pelvic girdle is closely attached along the posterior lower edge of the clavicle. The opposite sides are suturally attached along the median line, and together send back a long stout median spine through the middle of the ventral disk. Toward the anterior end each side bears a large foramen. The ventral fins are attached to the outer edges of the girdle, with their bases directed transversely across the body, or towards each other, rather than being attached, as in other forms, to the posterior ends of the girdle with their bases directed forward.

Vertebral, Rib and Fin Elements.

The abdominal vertebræ number 13, the caudal 19, making with the hypural a total of 33.

The first vertebra is expanded laterally to accommodate the wide occipital condyle. It bears no ribs. The abdominal vertebræ as viewed from below are smooth, without longitudinal ridges or pits, and are much constricted at the middle. On the side each bears a deep pit for the reception of the head of the rib. The last two abdominal vertebræ bear small parapophyses to the under side of the base of which ribs are attached. The base of each abdominal neural arch is expanded laterally over the head of each rib into a horizontal wing-like process, which grows small and disappears posteriorly. Anteriorly each projects in a point at the side of the preceding neural process. These processes are doubtless zygopophyses, though they might be considered parapophyses, as the ribs are expanded upward to their lower surface, were it not for the small processes on the last abdominal vertebræ which, however, prove themselves to be true parapophyses by passing into the hæmapophyses posteriorly. The caudal vertebræ grow more compressed backwards, and exhibit no peculiarities. In *Gobiesox* the vertebral formula is as follows: $14 + 21 + 1 = 36$. The zygopophyses project laterally as in *Caularchus* but are not expanded.

The hypural is symmetrical having a longitudinal incision dividing it into equal parts, each part bearing an equal number of caudal rays. There is no urostyle or other indication of

heterocercy. The spines of one vertebra anterior to the hypural assist in supporting the caudal fin.

Stout ribs are present on all of the abdominal vertebræ except the first one, and are continued back on the anterior caudal vertebræ. They are vertically flattened and grow smaller posteriorly. They project horizontally outward and to the lower surface near the tip of each is a bony ray which curves downward around the abdominal cavity. Gunther[1] describes these as follows: "The epipleurals are not much less developed than the ribs to the extremities of which they are suspended. We might also consider the ribs as long and detached parapophyses, and the epipleurals as the ribs proper." The presence of normal parapophyses on the last abdominal vertebræ prove the latter supposition to be incorrect, and if the distal bones are epipleurals they have changed their usual position on the superior surface near the bases of the ribs to the inferior surface near the tips of the ribs. The only other possibility is that they are extra intermuscular ossifications as occur in some fishes, notably the clupeoid fishes.

No trace of a spinous dorsal remains, and there are no accessory interneural rays in front of the soft dorsal. There are four unbranched ventral rays, and a short flat bone hidden under the skin in front of them representing a ventral spine, the rays are thick and their cross articulations are very close as in the thickened lower pectoral rays of the Cottoid fishes. I do not find in either *Gobiesox* or *Caularchus* the free ventral ray that Dr. Gunther found in *Chorisochismus dentex*.

The interspinal elements are normal in arrangement, and exactly coincide in number with the vertebral spines to which they are attached. No bony baseosts are developed.

Relationships.

The structure of the skeleton gives little help in assigning to the family Gobiesocidæ a definite phylogenetic position, and I find myself no nearer to a solution of the problem than Dr. Gill was when he wrote of these fishes in the "Standard Natural History," (Vol. III., p. 267) as follows: "There are no spines in any of the

[1] Cat. Fish. Brit. Mus., III., p. 493.

fins, and thus it has not even the technical characteristics of the true Acanthopterygians. Doubtless the parentage of the stock is to be looked for in that great suborder; but the divergence of the known forms has been so great that at present it cannot be certainly predicated whereabouts to find it."

I have examined skeletons of Cottoid, Blennioid, and Gobioid fishes with small results. The families Batrachididæ and Callionymidæ offer some slight indications of relationship to the Gobiesocidæ, and the weight of evidence is thrown towards the former family by the young of some or all of them having a ventral sucking disk just behind the base of the pectorals. The family Batrachididæ[1] further resembles the Gobiesocidæ in having the suborbital ring reduced to a small preorbital bone, only very small parapophyses present posteriorly, no myodome, and a single superior pharyngeal present on each side. As opposing the idea of relationship the Batrachididæ have five long actinosts, the posttemporal forms an integral part of the cranium, the palatine is normally joined to the pterygoid, and the mesopterygoid, metapterygoid, alisphenoid, and basibranchials are present.

The family Callynomidæ[2] resembles the Gobiesocidæ in having no mesopterygoid or metapterygoid, thus leaving the symplectic to form part of the anterior border of the cheek bones, in having no myodome or suborbitals, in the ventrals being widely separated, as well as in the general form of the body. The Callionymidæ, however, possess some important and well marked characters not possessed by the Gobiesocidæ, and these probably more than counterbalance the characters held in common. These characters are briefly: a spinous dorsal present; the ethmoid extending back and forming a bony interocular septum; the frontals reduced and occupying little more than the interorbital space; the posttemporal forming an integral part of the cranium; the actinosts all abutting against the hypocoracoid; the hypercoracoid foramen between the coracoid elements cutting an equal notch from each; the palato-quadrate arch normal; three superior pharyngeals present on each side; basibranchials

[1] In this family the following genera were examined: *Batrachoides*, *Opsanus* and *Porichthys*.

[2] *Calleonymus* was the only genus examined.

present; the neuropophyses and hæmopophyses ending each in two spines between which the interspinous elements fit.

SYNOPSIS OF CHARACTERS OF THE FAMILY GOBIESOCIDÆ.

Body broad and depressed in front, covered with smooth naked skin. Premaxillaries protractile. Strong teeth on dentary and premaxillary; none on vomer or palatines; pseudobranchiæ small or wanting. Gill fringes on two and a half or three arches. Occipital condyle partly formed by exoccipitals, which present articulating surfaces entirely lateral to that of the basioccipital. No supraoccipital crest present. Parietals separate or meeting over the surface of the supraoccipital. Myodome absent. No basisphenoid, alisphenoid, opisthotic, mesopterygoid or metapterygoid. Pterygoid reduced. Palatine connected to pterygoid only by a ligament. Preopercle developed backwards in a long triangular process, interposed between, and widely separating the interopercle from the subopercle. No suborbital ring. Basibranchials absent. Fourth ceratobranchial much lengthened. Superior pharyngeals one on each side. Hypohyal single on each side. Six branchiostegal rays. Posttemporal a single ray of bone without a lower limb. Supraclavicle attached just above middle of clavicle. Hypercoracoid foramen through middle of hypercoracoid. Actinosts hour-glass-shaped; two attached to each coracoid element. Postclavicle in two parts; the inferior part supporting the posterior edge of the ventral disk. Spinous dorsal absent. Ventrals each with a concealed spine and four unbranched rays. No airbladder. Parapophyses developed only posteriorly. Zygopophyses produced laterally. A ray of bone attached to each rib extending down around abdominal cavity.

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